

Method for Downhole Logging

5 The present invention relates to a method and equipment for measuring the properties of subsurface rock from a tool lowered down a borehole. In particular it relates to a method and equipment for measuring such properties as the response time and amplitude of the electrokinetic coefficient, porosity and permeability of fluid-bearing porous rocks.

10 The measurement of permeability of rocks surrounding a borehole is important in assessing the location of water or oil reserves, including the quality and quantity of the reservoir rock. Existing methods are unable to measure the permeability of a porous rock directly with any accuracy from a downhole tool.

15 In addition to its value in the assessment of the quality and quantity of water or oil reservoirs, rock permeability is very important in determining at what rate and at what cost these fluids can be produced from boreholes.

20 US Patent 4427944 discloses a method and apparatus for investigating the permeability of earth formations traversed by a borehole in which a source of mechanical excitation is positioned in contact with the surface of a borehole and actuated to excite the formation and produce an electrokinetic potential in the formation which is detected inside the borehole, measured and used to calculate the permeability.

25 Patent Application PCT/GB96/02542 discloses a method of measuring the properties of rock surrounding a borehole in which a seismic pulse is generated downhole which propagates outwards from the borehole to produce electrokinetic signals which are detected within the borehole and used to measure the properties of the surrounding rock. In this application the seismic pulse radiates outwards in all directions and this has been found to give superior results to uni-directional propagation of the seismic pulse as described in US Patent 4427944.

Sub  
C1  
30

We have now devised an improved method for downhole logging.

According to the invention there is provided a method for measuring the properties of a formation traversed by a borehole in which a directional seismic or sonic signal is generated downhole and is propagated into the surrounding formation and an electrokinetic signal generated by the seismic or sonic signal is detected by detecting means and in which the spatial distribution of the outgoing seismic signal is adjusted so that the electrokinetic signals are generated from different zones around the source.

The seismic signal is generated by the generation of a seismic or sonic shock downhole which propagates a seismic signal into the surrounding rock.

The distribution of the seismic signal can be varied in three dimensions so that it can be varied azimuthally with respect to source of the seismic shock in the borehole and can be rotated radially about a circle with the source at the centre of the circle, or by a combination of these two modes the distribution of the seismic signal can be varied in any direction.

The direction of the seismic signal can be varied mechanically by physically turning the source, for example a substantially uni-directional seismic source can be rotated so the direction of the seismic signal is rotated and it can be moved so that the direction of the seismic signal moves up and down. Alternatively the seismic signal can be propagated omni-directionally and a shield with an aperture or "window" can be positioned around the source so that the seismic signal propagates through the window; moving the location of the window e.g. by rotating the shield will cause the direction of the seismic signal to change.

Preferably the direction of the seismic signal is changed by wave interference or wave interaction of two or more sources acting together to produced a seismic signal which is focussed in a particular direction or location so that, by varying the frequency, amplitude and/or phases of the sources of the seismic shock the spatial distribution, direction and location of the outgoing seismic signal can be changed.

The superposition, constructive interference and combination of wave fronts to produce a spatially focussed wave is known and the calculations and controls need to produce a specified focussed wave are known.

- 5 In an embodiment of the present invention there are two or more separate sources of the seismic shock spaced apart from each other and there are means to vary the amplitude, frequency and/or phase independently. The source of the seismic shock preferably propagates a seismic signal in substantially all directions so that the direction of the combined signal produced can be varied in three dimensions.

10

The source of the seismic signal is preferably not in contact with the borehole wall but positioned substantially centrally within the borehole.

15

Each of the seismic signals is preferably propagated radially outwards in all directions through the borehole fluid (the fluid in the borehole e.g. drilling mud etc.) and, subject to distortion by the borehole wall and variations in the rock, the seismic signal propagates outwards substantially uniformly in all directions. It is the combination of two or more seismic signals which controls the total seismic signal generated and enables the direction to be changed.

20

The electrical signal generated within the surrounding rock is received and detected at the tool within the borehole from substantially the chosen location or direction.

25

This invention also provides apparatus for measuring the properties of rocks surrounding a borehole, which apparatus comprises a casing adapted to be lowered down a bore hole in which casing there is a seismic means for generating seismic signals and a means for varying the direction of the seismic signal and having associated therewith, a means adapted to detect electrical signals generated by the effect of a seismic shock generated by seismic means.

30

The means for generating the seismic signals preferably generates a series of pressure pulses or, more preferably, a continuous pressure oscillation, at one or more finite frequencies. It may consist of a mechanical vibrational device, an electromagnetic device, a sparker source, an explosive source, an airgun operated hydraulically or

09936790-09704

5

10

15

20

30

Preferably the means for detecting the electrical signals compares the potential at the ends, in the case of the dipole antenna, or measures the electrical field strength in the case of the coil. The potential at the ends of dipole antenna in the one case or of the coil in the other, are compared by connecting them to an amplifier in which the

The seismic signal can be generated whilst the apparatus is lowered or raised up from the borehole, thus providing a continuous or semi-continuous measurement of rock along the borehole

The seismic sources (3) and (4) are remotely controlled so the amplitude, frequency and/or phase of the shock they generate can be independently varied.

**PCT/GB00/00969**

- 7 -

- In use the tool (2) is lowered downhole and the seismic sources (3) and (4) operated to generate a seismic wave fronts shown by (7) and (8) in the surrounding rock formation. These wave fronts will generate an interference pattern within the rock formation to produce a focussed wave and a seismic signal will be generated which depends on the combination i.e. location of the focus, of the two wave fronts at any one location. By varying the amplitude, frequency and/or phases of the sources (3) and (4) the direction and strength of the signal formed by the combination of the signals from (3) and (4) can be controlled and varied in three dimensions.
- The electrodes (5) and (6) receive the electrokinetic signal generated by this combined seismic signal and it is transmitted to an amplifier and the computer for analysis and recording.

**Figure 6**